generating range data comprising a second plurality of three-dimensional points from the plurality of two-dimensional images using a range-data process;

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-dimensional points; and

triangulating the registered data, yielding at least one three-dimensional image of the oral cavity.

25. (New) The computerized method of claim 24, wherein the generating shape-from-shading data further comprises:

estimating the direction of the illuminant from the plurality of two-dimensional images, in reference to camera intrinsic parameters; and

determining a solution to a brightness equation, yielding the shape-from-shading data comprising a first plurality of three-dimensional points.

26. (New) The computerized method of claim 24, wherein the fusing the range data to the shape-from-shading data further comprises:

calculating the error difference in available depth measurements of the range data and the shape-from-shading data;

approximating a surface the fits the error difference, yielding an approximated surface; and

correcting the shape-from-shading data from the approximated surface, yielding fused data comprising a third plurality of three-dimensional points.

REMARKS

Applicant has reviewed the Office Action mailed on November 6, 2002. Claims 1, 5, 8, 11 and 20 are amended and claims 21 - 26 are added; as a result, claims 1 - 26 are now pending in this application.

§102 Rejection of the Claims

Claims 1-4, 8-10 and 16-19 were rejected under 35 USC § 102(e) as being anticipated by Carmeli et al. (U.S. 6,414,708).

Regarding amended independent claim 1, Applicant is unable to find, among other things, in the cited portions of Carmeli a method where shape-from-shading (SFS) data and range data are generated from the two-dimensional images, and where the SFS data and the range data are processed to generate the three-dimensional image(s), as recited in amended claim 1. Claims 2 – 4 depend on claim 1, are believed to be patentable at least for the reasons stated with respect to amended claim 1. Additionally, with respect to claim 3, Applicant is unable to find in the cited portions of Carmeli a method where a physical cast of the oral cavity is constructed from the three-dimensional image, as recited in the claim. Applicant respectfully requests withdrawal of the rejection, and reconsideration and allowance of claims 1 - 4.

Regarding amended independent claim 8, Applicant is unable to find, among other things, in the cited portions of Carmeli a computer-readable medium having computer-executable instructions to cause a computer to generate SFS data and range data using the plurality of two-dimensional images, and process the SFS data and the range data to generate the at least one three dimensional image, as recited in amended claim 8. Claims 9 and 10 depend on claim 8, and are believed to be patentable at least for the reasons stated with respect to amended claim 8. Additionally, with respect to claim 9, Applicant is unable to find in the cited portions of Carmeli a physical cast of the oral cavity constructed from the three-dimensional image, as recited in the claim. Applicant respectfully requests withdrawal of the rejection, and reconsideration and allowance of claims 8 - 10.

Regarding independent claim 16, Applicant respectfully traverses the rejection. The Office Action fails to make out proper prima facie anticipation because Carmeli does not describe all of the elements of claim 16. For example, Carmeli does not describe generating shape-from-shading data that is generated from a direction of an illuminant of the jaw that is estimated in reference to camera intrinsic parameters, as is recited in the claim. Applicant requests reconsideration and allowance of claim 16.

Regarding independent claim 17, Applicant respectfully traverses the rejection. Applicant is unable to find, among other things, in the cited portions of Carmeli, both a digitizer

providing five degrees of freedom, and a computer receiving coordinate measurements from the digitizer and generating a digital three-dimensional model from the coordinate measurements, as recited in the claim. Claims 18 and 19 depend on claim 17, and are believed to be allowable at least for the reasons provided with respect to claim 17. Additionally, with respect to claim 18, Applicant is unable to find in the cited portions of Carmeli a rapid prototyping machine operably coupled to the computer, receiving the digital three-dimensional model and generating a physical model of the digital three-dimensional model, as recited in claim 18. Further, with respect to claim 19, Applicant is unable to find in the cited portions of Carmeli, a display operably coupled to the computer, receiving the digital three-dimensional model and generating an image of the digital three-dimensional model, as recited in claim 19. Applicant respectfully requests withdrawal of the rejection, and reconsideration and allowance of claims 17 – 19.

Applicant does not admit that Carmeli is prior art under 35 U.S.C. § 102(e), and reserves the right to swear behind it at a later date. Nevertheless, Applicant respectfully submits that the claims are distinguishable over Carmeli for the reasons provided above.

Allowable Subject Matter

Claims 14 and 15 were allowed. Applicant thanks the Examiner for allowing the claims.

Claims 5-7, 11-13 and 20 were objected to as being dependent upon a rejected base claim, but were indicated to be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

New claim 21 recites language found in unamended claims 1 and 5. New claims 21-23 generally correspond to claims 5-7. New claim 24 recites language found in unamended claims 8 and 11. New claims 24-26 generally correspond to claims 11 - 13.

Claims 5–7 depend on and are believed to be patentable with amended independent claim 1. Claims 11-13 depend on and are believed to be patentable with amended independent claim 8. Claim 20 depends on and is believed to be patentable with independent claim 17.

Conclusion

Applicant respectfully submits that the claims are in condition for allowance and notification to that effect is earnestly requested. The Examiner is invited to telephone Applicant's attorney ((612) 373-6960) to facilitate prosecution of this application.

Please charge the additional claims fee of $138.00, and any additional fees deemed necessary, to Deposit Account No. 19-0743.

Respectfully submitted,

ALY A. FARAG ET AL.

By their Representatives,

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Date 2-4-03 By _____
Marvin L. Beekman
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CERTIFICATE UNDER 37 CFR 1.8: The undersigned hereby certifies that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail, in an envelope addressed to: Commissioner of Patents, Washington, D.C. 20231, on this 4th day of February, 2003.

GREG HANSON _____
Name Signature

Docket No. 01160.012US1

Clean Version of Pending Claims

SYSTEM AND METHOD FOR 3-D DIGITAL RECONSTRUCTION
OF AN ORAL CAVITY FROM A SEQUENCE OF 2-D IMAGES
Applicant: Aly A. Farag et al.
Serial No.: 09/842,587

Please replace the previously pending claim set with the claims, as amended, below:

A1 Sub B1

1. (Amended) A computerized method for dental imaging comprising:

receiving a plurality of two-dimensional images of a oral cavity; and

generating at least one three-dimensional image of the oral cavity from the plurality of two-dimensional images, including:

generating shape-from-shading (SFS) data and range data using the plurality of two-dimensional images; and

processing the SFS data and the range data to generate the at least one three-dimensional image.

Dep B2

2. The computerized method of claim 1, wherein the plurality of two-dimensional images further comprises a plurality of two-dimensional optical images.

3. The computerized method of claim 1, further comprising:

constructing a physical cast of the oral cavity from the three-dimensional image.

4. The computerized method of claim 1, further comprising:

generating the plurality of two-dimensional images of the oral cavity from a common reference point in three-dimensional space.

5. (Amended) The computerized method of claim 1, wherein processing the SFS data and the range data to generate the at least one three-dimensional images comprises:

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-dimensional points; and

triangulating the registered data, yielding the at least one three-dimensional image of the oral cavity.

6. The computerized method of claim 5, wherein the generating shape-from-shading data further comprises:

estimating the direction of the illuminant from the plurality of two-dimensional images, in reference to camera intrinsic parameters; and

determining a solution to a brightness equation, yielding the shape-from-shading data comprising a first plurality of three-dimensional points.

7. The computerized method of claim 5, wherein the fusing the range data to the shape-from-shading data further comprises:

calculating the error difference in available depth measurements of the range data and the shape-from-shading data;

approximating a surface the fits the error difference, yielding an approximated surface; and

correcting the shape-from-shading data from the approximated surface, yielding fused data comprising a third plurality of three-dimensional points.

8. (Amended) A computer-readable medium having computer-executable instructions to cause a computer to perform a method comprising:

receiving a plurality of two-dimensional optical images of an oral cavity; and

generating at least one three-dimensional image of the oral cavity from the plurality of two-dimensional images, including:

generating shape-from-shading (SFS) data and range data using the plurality of two-dimensional images; and

processing the SFS data and the range data to generate the at least one three-dimensional image.

9. The computerized method of claim 8, further comprising:

constructing a physical cast of the oral cavity from the three-dimensional image.

10. The computerized method of claim 8, further comprising:

generating the plurality of two-dimensional images of the oral cavity from a common reference point in three-dimensional space.

11. (Amended) The computerized method of claim 8, wherein processing the SFS data and the range data to generate the at least one three-dimensional images comprises:

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-dimensional points; and

triangulating the registered data, yielding the at least one three-dimensional image of the oral cavity.

12. The computerized method of claim 11, wherein the generating shape-from-shading data further comprises:

estimating the direction of the illuminant from the plurality of two-dimensional images, in reference to camera intrinsic parameters; and

determining a solution to a brightness equation, yielding the shape-from-shading data comprising a first plurality of three-dimensional points.

13. The computerized method of claim 11, wherein the fusing the range data to the shape-from-shading data further comprises:

calculating the error difference in available depth measurements of the range data and the shape-from-shading data;

approximating a surface the fits the error difference, yielding an approximated surface; and

correcting the shape-from-shading data from the approximated surface, yielding fused data comprising a third plurality of three-dimensional points.

14. A three-dimensional digital image of a human oral cavity produced by the process comprising:

generating a plurality of two-dimensional optical images of the oral cavity from a common reference point in three-dimensional space;

generating shape-from-shading data from the plurality of two-dimensional images using a shape-from-shading process, the shape-from-shading data comprising a first plurality of three-dimensional points;

generating range data comprising a second plurality of three-dimensional points from the plurality of two-dimensional images using a range-data process;

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-dimensional points; and

triangulating the registered data, yielding the one three-dimensional image of the oral cavity.

15. The three-dimensional digital image of a human oral cavity of claim 14, produced by the process wherein generating shape-from-shading data further comprises:

estimating the direction of the illuminant from the plurality of two-dimensional images, in reference to camera intrinsic parameters.

16. A system for dental diagnosis comprising:

a processor; and

software means operative on the processor for generating a three-dimensional image of a human jaw, including generating shape-from-shading data that is generated from a direction of an illuminant of the jaw that is estimated in reference to camera intrinsic parameters.

17. A computerized system comprising:

a digitizer providing five degrees of freedom, having an arm;

a charge coupled device camera, rigidly mounted on the arm of the digitizer; and

a computer, operably coupled to the digitizer and the camera; receiving coordinate measurements from the digitizer and a plurality of two-dimensional images from the camera; and generating a digital three-dimensional model from the coordinate measurements and from the plurality of two-dimensional images.

18. The computerized system of claim 17, further comprising:

a rapid prototyping machine operably coupled to the computer, receiving the digital three-dimensional model and generating a physical model of the digital three-dimensional model.

19. The computerized system of claim 17, further comprising:

a display operably coupled to the computer, receiving the digital three-dimensional model and generating an image of the digital three-dimensional model.

20. (Amended) The computerized system of claim 17, the computer further comprises:

a computer readable medium comprising means of:

generating shape-from-shading data from the plurality of two-dimensional images using a shape-from-shading process, the shape-from-shading data comprising a first plurality of three-dimensional points;

generating range data comprising a second plurality of three-dimensional points from the plurality of two-dimensional images using a range-data process;

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-dimensional points; and

triangulating the registered data, yielding the image of the three-dimensional model.

21. A computerized method for dental imaging comprising:

receiving a plurality of two-dimensional images of a oral cavity; and

generating shape-from-shading data from the plurality of two-dimensional images using a shape-from-shading process, the shape-from-shading data comprising a first plurality of three-dimensional points; and

generating range data comprising a second plurality of three-dimensional points from the plurality of two-dimensional images using a range-data process;

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-

dimensional points; and

triangulating the registered data, yielding at least one three-dimensional image of the oral cavity.

22. The computerized method of claim 21, wherein the generating shape-from-shading data further comprises:

estimating the direction of the illuminant from the plurality of two-dimensional images, in reference to camera intrinsic parameters; and

determining a solution to a brightness equation, yielding the shape-from-shading data comprising a first plurality of three-dimensional points.

23. The computerized method of claim 21, wherein the fusing the range data to the shape-from-shading data further comprises:

calculating the error difference in available depth measurements of the range data and the shape-from-shading data;

approximating a surface the fits the error difference, yielding an approximated surface; and

correcting the shape-from-shading data from the approximated surface, yielding fused data comprising a third plurality of three-dimensional points;

24. A computer-readable medium having computer-executable instructions to cause a computer to perform a method comprising:

receiving a plurality of two-dimensional optical images of an oral cavity; and

generating shape-from-shading data from the plurality of two-dimensional images using a shape-from-shading process, the shape-from-shading data comprising a first plurality of three-dimensional points;

generating range data comprising a second plurality of three-dimensional points from the

plurality of two-dimensional images using a range-data process;

fusing the range data to the shape-from-shading data, yielding fused data comprising a third plurality of three-dimensional points;

registering the fused data, yielding registered data comprising a fourth plurality of three-dimensional points; and

triangulating the registered data, yielding at least one three-dimensional image of the oral cavity.

25. The computerized method of claim 24, wherein the generating shape-from-shading data further comprises:

estimating the direction of the illuminant from the plurality of two-dimensional images, in reference to camera intrinsic parameters; and

determining a solution to a brightness equation, yielding the shape-from-shading data comprising a first plurality of three-dimensional points.

26. The computerized method of claim 24, wherein the fusing the range data to the shape-from-shading data further comprises:

calculating the error difference in available depth measurements of the range data and the shape-from-shading data;

approximating a surface the fits the error difference, yielding an approximated surface; and

correcting the shape-from-shading data from the approximated surface, yielding fused data comprising a third plurality of three-dimensional points.